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KEEP CROP RESIDUES ON THE SURFACE OF THE GROUND

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Research data show that any form of crop residue is more effective in reducing runoff and soil loss by erosion when kept on the surface of the ground than when turned under. The data also indicate that leaving the crop residue on the surface is a more effective way of building up the organic matter content, of improving the aggregation and of maintaining a high infiltration rate of the soil than turning it under. In many cases residue on the ground surface is equally satisfactory in maintaining a high level of crop production.

Vegetal covers, whether living or dead, accomplish these objectives. Likewise, residue material, whether left on the surface or turned under, is superior to no crop residue. The use of crop residue on the surface offers a satisfactory means of supporting those places in crop rotations where the rotation crops themselves do not provide adequate protection for the soil against the action of the raindrop during hazardous periods of high impact storms. The vegetal cover absorbs the energy of the falling raindrops and prevents the destructive action of their beating on bare land.

Duley and Russell (5) found that where water was applied artificially to 0.005-acre plots at the rate of about 1.5 inches per hour to simulate rainfall, wheat straw stubble left on the surface almost completely eliminated erosion and reduced runoff about 95 per cent over that of a bare cultivated Marshall silt loam with a four per cent slope. Out of a total of 15.33 inches of water applied to the bare cultivated soil 6.27 inches entered the ground and the other 9.06 inches ran off taking 3.44 tons of soil per acre with it. At the same time 15.54 inches, out of 15.96 applied to a similar soil covered with combine wheat stubble, entered the ground leaving only 0.42 inch to runoff, which carried 0.03 ton of soil with it.

The foregoing results compared favorably with results obtained under field conditions during the fallowing seasons of 1939-41, inclusive. The average annual rainfall for the three fallow seasons, which included the period of April-September, was 12.43 inches. The average annual runoff for the period was 1.97 inches for a disked plot which received no organic matter, 1.39 inches for a similar plot receiving 2 tons of wheat straw disked in, and 0.60 inch for a plot receiving two tons of wheat straw and subtilled. The soil losses per acre were 13.04 tons for the disked plot, 6.24 for the straw disked in, and 0.97 ton for the plot subtilled.

During this period the plot with the straw disked in, lost more than twice as much water by runoff and 6 times as much soil as where the straw was on the surface. Bare disked land lost 3 times as much water and 13 times as much soil as an adjoining stubble plot with residues on the surface.

Woodburn (18) found that 2 tons of straw, applied as a mulch after the land had first been cultivated, reduced erosion to 0.1 ton per acre and

the runoff to 6 per cent. During the same period a bare soil lost 21 tons of soil and 44 per cent of the rainfall as runoff. The experiment was conducted on Houston clay. The time extended from July 1 to December 31, 1942 during which a total of 14.83 inches of rain fell.

Peele (14) found that oat hay and crimson clover used at the rate of 2.5 tons per acre as mulching material reduced runoff and soil loss on 4 different soil types during the period of June 16 to November 23, 1944. The average runoff for the 4 soil types was 18.04 per cent for bare land, 1.25 for oat hay mulch and 0.33 for crimson clover mulch. The soil loss was 2,428 pounds per acre for the bare land, 61 for the oat hay mulch and 20 for the crimson clover mulch. An average of 14.5 inches of rain fell during the period.

The use of 4 tons per acre of crimson clover and Kobe lespedeza, as a mulch on Cecil clay, reduced runoff from 48.4 per cent of the total rainfall of 94.43 inches to 3.5 per cent, and the soil loss from 178,300 pounds per acre for an unmulched plot to 1,500 pounds per acre for the mulched plot. The period covered was August 1939 to January 1942.

Hendrickson, Carreker and Adams (7) report soil loss of 12.57 tons per acre and runoff 32.75 per cent of a total rainfall of 25.27 inches for unmulched soil for the period of April to September 1940, compared with corresponding losses of 2 tons of soil and 1.43 per cent of rainfall as runoff for soil mulched with three to four tons straw per acre.

The primary effect of vegetal cover in reducing runoff and soil loss was generally conceded to be due to the impediment it offered to overland flow until Borst and Woodburn (2) showed it to be due to the deenergizing of the rain drop instead. They applied artificial rain to 3 series of plots at the rate of approximately 2.25 inches per hour. The plots were left bare and exposed to the action of natural rains for some weeks. During this period the surface soil became crusted or "sealed". Two of these series of plots were then covered with straw at the rate of 2 tons per acre. In one series, the straw was placed directly on the ground and in the other it was supported 1 inch above the surface of the ground on chicken wire. The third series was left bare. Artificial rain was then applied at the above mentioned rate. It was found that 92.7 per cent of the water applied ran off the bare plot compared with 65.0 per cent for the plot with the mulch placed directly on the soil and 83.2 per cent for the plot where the mulch was supported 1 inch above the ground. The corresponding soil losses for the three plots were 5.62 tons per acre for the bare, 0.42 ton for the first mulched plot and 0.26 ton for the mulched plot where the straw was supported 1 inch above the ground.

These figures show that the mulch was not very effective in controlling runoff when applied after the surface of the soil had become sealed but did materially reduce the rate of soil loss. Had surface flow been the chief factor in bringing about erosion, the rate of soil loss should have been much higher on the plots where the mulch was supported 1 inch above ground than on the plot where the mulch was placed directly in contact with the soil.

Further light was shed on this point by use of 2 additional series of plots on which the surface of the soil was broken to a depth of about 1 inch and straw mulch applied at the rate of 2 tons per acre. In one series the mulch was placed directly on the surface of the ground and in the other it was supported 1 inch above the surface on chicken wire. Water was applied at the usual rate of 2.25 inches per hour.

The mulch in this instance almost completely eliminated both runoff and erosion. The plot with the mulch resting directly on the surface of the ground lost 1.7 per cent of the water applied as runoff and 0.10 ton of soil per acre. The other plot lost 1.2 per cent of the water applied as runoff and 0.12 ton of soil.

These studies show that the chief function of the straw was energy absorption or protection from raindrop impact and not the impediment of overland flow.

Lamb (11) found that 10 tons of manure used as a top dressing after planting consistently saved much more soil and water than did 20 tons plowed under during the period 1943-48, inclusive, and produced as satisfactory crop yields. At the end of the sixth year of the experiment the level of organic matter of the soil appeared to be more closely related to the method of application and the amount of erosion that occurred than to the amount of manure applied.

Lamb, Andrews and Gustafson (12) reduced the loss of water to less than one-half and the loss of soil to less than one-fourth by leaving 750 pounds of buckwheat straw per acre on the surface as a mulch. Records for 2 years show that plots with residues plowed under lost an average of 2.4 inches of water and 2.2 tons of soil an acre, for the period June 10 to December 1 of each year 1942 and 1943.

Six tons of straw mulch per acre on Groton soil with a slope of 35 to 45 per cent reduced runoff on the average from 1.93 inches for fallow to 0.16 inch and soil loss from 9,132 pounds per acre to only a trace during the period May through October during each of the 3 years 1940-42. Soil mulched with an average of 12 tons of straw per acre per season for 1939-40 produced an average acre yield of 7,125 pounds of grapes compared with 5,325 pounds for a similar area clean cultivated. In 1941 there was little difference in yield, and some evidence of late growth and winter injury caused by an over supply of nitrogen was noted.

Van Doren and Stauffer (16) found that soil losses ranged from 14 to 149 times greater from unmulched plots than from plots protected by straw mulch. Wheat straw, corn stover and soybean residue were the materials used. Alderfer and Merkle (1) found that mulches composed of manure, straw, sawdust, corn stover, oak leaves and pine needles completely eliminated runoff on Hagerstown silt loam where water was applied at the rate of 1.5 inches per hour. Three and four years of mulching with these

materials resulted in complete control of surface runoff and effected an infiltration capacity equal to, or in excess of, 3 inches per hour.

In addition to controlling runoff and erosion more effectively when left on the surface than when turned under crop residue on the surface builds up the organic matter content of the soil at a faster rate than when turned under. Moser (13) found that by turning under 4 tons of crimson clover per acre the organic matter content of the soil was increased from 1.75 per cent, where no residue was applied, to 2.52 where the crimson clover was turned under. When applied to the surface as a mulch the organic matter content of the soil increased to 2.54 per cent. Under similar conditions where lespedeza residue was allowed to accumulate to form a natural mulch the organic matter content of the soil increased to 3.74 per cent.

Peele (14) found that by using 4 tons of Kobe lespedeza hay per acre as a mulch the runoff was held to 3.4 per cent of a total rainfall of 94.43 inches during the period under study. The soil loss was 1,500 pounds per acre. An adjoining plot which had 4 tons of Kobe lespedeza hay turned under lost 42.7 per cent of the total rainfall as runoff and 107,700 pounds of soil per acre.

Alderfer and Merkle (1) found important differences in the organic matter content of the soil at three different depths at the end of the fourth year in favor of leaving crop residue on the surface rather than turning it under. The organic matter content was determined for 0-1 inch depth, 1-3 inch depth, and 3-6 inch depth in each case. The mulched plot had 3.72 per cent organic matter for the 0-1 inch depth compared with 2.71 per cent for the plot where the crop residue was turned under. Corresponding figures for the 1-3 inch depth were 3.11 per cent for the mulched plot and 2.89 for the plot where the residue was turned under, and 2.75 and 2.55 per cent, respectively, for the mulched and incorporated plots for the 3-6 inch depth. These figures are the averages for 6 different kinds of organic materials used.

Van Doren and Stauffer (16) found that soil aggregation was very definitely favored by mulching with straw. Alderfer and Merkle (1) found that the average stability index of the soil was definitely higher in each depth, namely, 0-1 inch, 1-3 inches and 3-6 inches where the crop residue remained on the surface than where turned under. The stability index for the 0-1 inch depth was 57.9 on the mulched plot compared with 54.2 on the plot where the residue was turned under. Corresponding figures for the 1-3 inch depth were 59.0 and 55.9 and for the 3-6 inch depth 60-7 and 58.8.

Havis (6) found that Wooster silt loam soil reached a relatively high state of aggregation under straw mulch such as that often applied around fruit trees. This condition is reached quickly if the mulch is of unleached wheat and alfalfa. Bluegrass sod treatment over a long period is of value in increasing and maintaining a high percentage of the aggregates of the larger size but is not as effective as mulch. Cultivation, even with such cover crops as can be produced in a mature apple orchard, is very destructive of soil aggregate structure. Mulch has a value in the formation of aggregates which is out of proportion to differences in organic matter present.

Kidder, Stauffer and Van Doren (9) found that total infiltration was greatly increased by the presence of wheat straw mulch on 3 different occasions. Tests were made in June 1941, October 1941 and again in April 1942 on soybean and corn land. The average total infiltration for the first 60 minutes for the 3 different dates and the 2 crops was .56 inch on the bare land and 1.67 on the mulched soil. Findings of other investigators verify these results.

Crop yields are also higher in some instances where residue material is left on the surface than where turned under. Hendrickson and Crowley (8) obtained as high or higher yields of lespedeza hay during 1939 and 1940 from eroded abandoned land that had been mulched as from ordinary farm land in the vicinity which was cultivated the conventional way. A complete failure was experienced where lespedeza was planted on eroded abandoned land that was not mulched, however. These mulched eroded abandoned areas produced 282 pounds of lespedeza seed per acre in 1942. This equaled or exceeded the seed yields obtained on the best of the cropland fields. Peele (14) secured higher corn yields on 4 different soil types where mulches were used than where no mulching material was used. The average acre yield for the 4 soil types where no mulch was used was 17 bushels. Comparable plots mulched with oat hay produced 21.3 bushels and other plots mulched with crimson clover produced 28.4 bushels per acre. Copley, Britt and Posey (4) found that flue cured tobacco produced greater yields, when mulched than when not mulched, during years of normal or below normal rainfall. However, the yields on the mulched plots were lower than those of unmulched plots during seasons of excess rainfall. Duley and Russell (5) report an average annual acre yield of 28.3 bushels of corn on unmulched land for the 3 year period 1939-41, compared with a yield of 36.8 bushels for land mulched with 2 tons straw per acre. They also found that corn yields were higher on land where the straw was left on the surface than where it was turned under. Corn following small grain with the stubble plowed under produced 21 bushels per acre compared with a yield of 27.3 bushels per acre where the stubble was subtilled.

Van Doren and Stauffer (16) reported that the use of 2 tons of wheat straw per acre as mulch depressed corn yields, increased soybean yields slightly, and did not affect the yield of hay materially. Mulched corn land produced an average annual acre yield of 76.5 bushels of corn for the 3 year period 1941-43 compared with a yield of 92.7 bushels for unmulched land. During the same period soybeans produced 31.5 bushels per acre on the mulched land and 29.2 bushels on the unmulched land. The corresponding yields of hay were 3.17 and 3.19 tons per acre.

Van Doren, Lang and Waggoner (15) stated that the depressing effects of mulch on corn yield were overcome when the soil was fertilized. The average acre yield of corn on unmulched land on four farms in 1943 was 65 bushels per acre compared with 64 bushels for mulched land. Similarly the average acre yield of unmulched land on 5 farms in 1944 was 79.6 bushels per acre compared with a yield of 77.9 bushels per acre for mulched land.

Whitfield, Van Doren and Johnson (17) found that sub-tilled stubble mulch wheat out yielded moldboard plowed and one-wayed wheat where wheat was grown continuously during the period 1942-48, inclusive, and that sub-tilled wheat out yielded one-wayed wheat where wheat alternated with fallow during 1943-48, inclusive. Pullman silty clay loam was used in both sets of tests.

The moldboard plowed wheat produced an average annual yield of 12.5 bushels per acre on the continuous wheat plots compared with 13.2 bushels for the one-wayed and 15.1 for the sub-tilled. The yield was 18.8 bushels per acre for the one-wayed and 21.6 for the sub-tilled plots where wheat alternated with fallow. The beneficial effects of sub-tillage were accumulative and the spread between the yields on the sub-tilled and moldboard and one-way plowed plots became progressively greater with time.

The stubble mulch plots also were slightly higher in organic matter content in 1948 than the one-way tilled plots.

Borst and Yoder (3) found that alfalfa could be grown successfully on severely eroded abandoned land without preparing the seedbed the customary way but by utilizing the poverty grass and broomsedge growth on such lands as a mulch. The land was limed, fertilized and disked so as to cut up the sod cover in such a way as to leave it on the surface as a mulch. Alfalfa grown by this method produced as large, or larger, yields of hay per acre as alfalfa grown on good land and cultivated by conventional methods.

Kurtz, Appleman and Bray (10) used growing plants for surface protection in growing corn. Second year red clover and sweet clover were turned under in narrow strips where corn rows were to be placed and the clover between the rows was clipped close to the ground when the corn was planted. The sweet clover was killed by this clipping and remained as a mulch on the unplowed strips between the rows. A modification with oats as the intercrop was also included. In the red clover areas the clover grew tall enough to necessitate clipping a month and again 6 weeks after the corn was planted. All plots under this corn-clover association were paired with adjacent plots which were spaded and cultivated to simulate the conventional seedbed preparation and management.

Three series of plots were used in connection with both red clover and sweet clover. One series was untreated, one received nitrogen fertilizer and the other received nitrogen fertilizer and water. The corn yields for the different treatments are given in the following table:

YIELD OF CORN UNDER DIFFERENT MANAGEMENT SYSTEMS (Bu Per Acre)

Intercrop	Slit-crop system	Conventional system	Oats system	Intercrop	Slit-crop system	Conventional system	Oats System
Red clover	69	126		Sweet clover	116	132	
Red clover + N	102	125	110	Sweet clover +N	116	130	120
Red clover + N + water	130	135		Sweet clover +N + water	131	140	

Very limited trials with soybeans in the slit-cropping system were inconclusive. Although the yields were lower under the slit system, possibilities for good soybean yields were indicated whenever proper management techniques are developed. The corn yields doubtless would have been much higher on the slit-crop plots with red clover had the clover been clipped more often and the nitrogen and water applied at the proper time.

The advantages of a slit-cropping system may be great enough to warrant its use even though somewhat smaller yields may be obtained. This is particularly true for situations where erosion control and soil conservation are primary considerations. The possibility of reducing the plowing and cultivation currently necessary for corn production is alone sufficient to warrant futther trails with a slit-cropping system.

SUMMARY

The data presented here indicate that the most effective way to utilize crop residues and other vegetal covers is to keep them on the surface of the ground, rather than turn them under. The data also show that the proper use of these materials offers the most effective single measure of reducing erosion and runoff and bringing about other desirable conditions in cultivated soils leading to continued high production.

Crop residues and other vegetal covers are more effective in building up the organic matter content of the soil when left on the surface than when turned under. They are also more effective in improving the aggregate structure and infiltration capacity of the soil when left on the surface. Surface utilization of these materials lead to substantial increases in crop yields in many instances. Further investigation doubtless will reveal satisfactory methods of overcoming the depressing effects of mulch covers on crop yields, where they occur, and lead to even greater increases under those conditions producing superior yields now. They offer an exceptional opportunity for bridging the gaps existing in crop rotations where the covers from the rotation crops themselves do not furnish adequate protection from the destructive action of the falling raindrop.

The chief function of crop residues and other vegetal covers in reducing erosion is energy absorption or protection from raindrop impact and not the impediment of overland flow. When left on the surface, vegetal covers deenergize the falling raindrop, thereby eliminating the destructive action of raindrop splash. This in turn prevents the chain of damaging reactions

which the splashing raindrop sets in motion. To be sure, we do not have the final answer or answers to the correct use of crop residues, nor of other vegetal covers, in this capacity. We do have enough information, however, to indicate that these hold the key to the erosion control problem on cultivated land.

Our present situation in this connection may be compared with the Wright brothers' first attempt to fly an airplane. The research data available to them indicated it was possible to build a machine that would fly. Once they proved their point research engineers busied themselves with building better machines. We now have found a practice that will control raindrop splash. Since our objective is to save our soil we have a far greater incentive for forging ahead with a program which has for its aim more complete knowledge of the proper ways of utilizing crop residues and other vegetal covers in conserving our soil and water.

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